ELEMENTAL CARBON CONCENTRATIONS: ESTIMATION OF AN HISTORICAL DATA BASE

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Abstract

While recent advances in instrumentation permit routine determination of elemental carbon concentrations in atmospheric aerosol samples, historical data on elemental carbon concentrations are absent. Two methods are available for the estimation of an historical data base for elemental carbon concentrations: calibration of reflectance-based tape samplers and analysis of archived high volume sampler filters. These methods are described and applied to the problem of reconstructing an historical data base for elemental carbon concentrations in Los Angeles. Twenty-four year average elemental carbon concentrations at seven monitoring sites in the Los Angeles area are estimated to range from 6.4 $\mu g\ m^{-3}$ at Downtown Los Angeles to 4.5 $\mu g\ m^{-3}$ at West Los Angeles. At most monitoring sites studied, elemental carbon concentrations were lower in recent years than during the late 1950's and early 1960's.

1.0 Introduction

Samples taken throughout the United States show that carbon containing particles typically contribute from 3% to more than 30% of the total atmospheric aerosol mass (Mueller et al., 1982; Wolff et al., 1982; Shah, 1981). Carbonaceous aerosols consist of organic compounds plus black non-volatile components that have a chemical structure similar to impure graphite (commonly called elemental carbon, graphitic carbon, or sometimes just soot). A small amount of carbonate carbon also may be present. Graphitic or elemental carbon particles have been shown to be the dominant light absorbing aerosol species in the atmosphere, and have been related to visibility reduction in Denver, Los Angeles, New York and other cities (Rosen et al., 1978; Waggoner and Charlson, 1977; Pierson and Russell, 1979; Conklin et al., 1981; Groblicki et al., 1981; Wolff et al., 1982). Soots have been found to be carcinogenic in experimental animal studies and hence are of current public health concern (IARC Working Group, 1980).

Over the past decade, a variety of thermal evolution, combustion, nuclear chemical, and optical methods have been developed that permit quantitative determination of elemental carbon concentrations (Cadle et al., 1980; Cadle and Groblicki, 1982; Huntzicker et al., 1982; Macias and Chu, 1982; Mueller et al., 1982; Pierson and Russell, 1979; Pimenta and Wood, 1980; Rosen et al., 1982). Because of the relatively recent introduction of most of these methods, no long-term historical routine air monitoring data bases exist sufficient to describe long-term elemental carbon concentration trends or to support retrospective

health effect and visibility studies. This lack of an historical data base for elemental carbon concentrations is particularly important in Los Angeles. Elemental carbon concentrations in that city are likely to rise significantly if large numbers of passenger cars with diesel engines are introduced into the vehicle fleet (Pierson, 1978).

An historical data base for elemental carbon concentrations can be estimated by two methods. Tape samplers that for many years have been used to take reflectance measurements of the "blackness" of particulate samples on a filter tape can be calibrated in terms of equivalent elemental carbon concentrations. Alternatively, archived high volume sampler filters taken in past years can be analyzed to determine their elemental carbon content. In this paper, each of these approaches is described and then compared using data collected in the Los Angeles Basin.

2.0 The Historical Km Sampler Data Base

Between 1958 and mid-1981, the South Coast Air Quality Management District (SCAQMD) and its predecessor agencies collected consecutive hourly average measurements of particulate matter concentrations in Km units. As described by Hall (1952), the Km unit is a reflectance measurement of the darkness of an aerosol deposit on a filter tape. Ambient air is drawn through a one-square-inch (5.07 cm^2) area of filter paper at a rate of 25 ft^3 per hour (11.8 lpm) for 51.5 min of each hour. The blackness of the deposit on the filter tape is measured by the ratio of the intensity of reflected light from a clean portion

of a blank filter segment, R_o, to light reflected from the aerosol sample, R. The Km unit is related to reflectance by the formula (Holland and MacPhee, 1958):

$$Km = \frac{2280}{v_m} \log_{10} \frac{R_o}{R} \quad (1)$$

where v_m is the air volume sampled during each 51.5 min period (std. cu ft. at 1 atm., 70°F).

Elemental carbon samples examined by laboratory reflectometers show that the blackness of those samples is due to their elemental carbon content and that elemental carbon concentrations can be expressed with reasonable accuracy as a linear function of the log of the reflectance ratio R_o/R (Delumyea et al., 1980). Elemental carbon concentrations thus should be directly proportional to aerosol loadings evaluated in Km units. Conklin et al. (1981) verified this relationship between Km sampler response and elemental carbon concentrations. The method used to do this is described below.

3.0 Winter 1980 Experiments

During January and February, 1980, a series of experiments was conducted in the Los Angeles area designed to provide baseline data on wintertime particulate organic and elemental carbon concentrations in that community. Simultaneous samples were taken in parallel with the Km instruments at South Coast Air Quality Management District monitoring stations in Downtown Los Angeles and Pasadena. As a result, those Km instruments were calibrated to read in terms of equivalent elemental carbon concentrations.

Data were sought that would represent peak elemental carbon concentrations. Since elemental carbon is a primary pollutant emitted from combustion processes, historical data on carbon monoxide and total oxides of nitrogen concentrations were examined as tracers for primary combustion pollutants. Peak CO and NO_x concentrations in Los Angeles occur during winter morning peak traffic hours. On that basis, the sampling program was scheduled for 10 weekday mornings during the period January 15 to February 26, 1980.

Samples for total aerosol mass, total carbon, elemental carbon, trace metals and aerosol light absorption coefficient determination were taken hourly from 7 am to 1 pm on each day of interest. Methods employed are summarized in Table 1. Air inlet configurations were matched to the operating conditions of the Km samplers, and samples were collected for 51.5 minutes of each hour. Aerosol carbon samples were collected on 47 mm Pallflex Tissuquartz Filters that had been prefired to 900°C for 1-1/2 hours to reduce their carbon blank. These filters were placed into filter holders between two pieces of metal shim stock that masked all but a 0.32 cm^2 spot in the center of each filter, thus reducing the area exposed to air flow when in use. Ambient air was drawn through these filters at a nominal rate of 12 l/min.

Filter deposits were analyzed for total carbon by the Gamma Ray Analysis of Light Elements (GRALE) technique (Macias et al., 1978). Elemental carbon concentrations on the same filters were obtained by two methods. First, elemental carbon concentrations were determined by

reflectance calibrated against heated butane soot standards. Then 16 of the 53 samples taken were analyzed for elemental carbon by the GRALE technique after heating those samples to eliminate volatile organics. Both elemental carbon measurement methods are described by Delumyea et al. (1980), and results of the reflectance analyses are reported by Conklin et al. (1981). Analysis of the elemental carbon content of these filters using the laboratory reflectometer calibrated by Delumyea et al. (1980) introduces a second optical instrument into this experiment in addition to Km samplers. Analysis of elemental carbon by more than one method (i.e. both reflectance and GRALE) further requires that a precise distinction be drawn between different data sets. In the discussion of the winter 1980 experiment that follows, mention of elemental carbon concentrations measured by reflectance always refers to the results from the low-volume quartz fiber filter samples shown in Table 1 that were evaluated by the reflectance method of Delumyea et al. (1980). Km sampler data are identified separately by reference to Km units, and elemental carbon measured by GRALE is always identified by reference to the GRALE technique.

Light absorption by elemental carbon is dependent on particle size and morphology (Faxvog and Roessler, 1978; Roessler and Faxvog, 1979). Accurate measurement of elemental carbon concentrations by reflectance demands that the calibration standards used (in this case a heated butane soot) resemble ambient elemental carbon. A comparison of the GRALE technique and the reflectance standards used in this study for measurement of ambient elemental carbon concentrations has been

conducted for St. Louis aerosol samples by Delumyea et al. (1980). Their analysis shows that for elemental carbon measured in $\mu g\ cm^{-2}$ of filter surface over the range 0-30 $\mu g\ cm^{-2}$

$$EC_{GRALE} = (0.9 \pm 0.2)\ EC_{REFLECT} + (3 \pm 4) \qquad (2)$$

with a correlation coefficient of 0.96. They conclude that the particular reflectance standards used here have properties representative of ambient elemental carbon, but that some non-elemental carbon may remain in the standards after heat treatment in air at 300°C. In that case elemental carbon concentrations judged against these reflectance standards may be overestimated.

Additional aerosol samples were taken each hour on Nuclepore polycarbonate membrane filters (0.4 μm pore size) operating at an air flow of 20 l/min. These filters were analyzed for total mass by gravimetric methods, for trace metals concentrations by X-ray fluorescence, and for aerosol light absorption coefficient by the integrating plate technique (Lin et al., 1973, as modified by Ouimette, 1980). Results of those analyses are reported elsewhere (Conklin et al., 1981).

Winter morning average elemental carbon and total carbon concentrations are shown in Figure 1. Values given represent averages of the hourly low-volume quartz fiber filter samples that were analyzed for total carbon by GRALE and for elemental carbon by reflectance using the technique of Delumyea et al. (1980). At Downtown Los Angeles, total carbon averaged 24.4 $\mu g\ m^{-3}$,

while elemental carbon concentrations averaged 9.0 μg m^{-3} based on 28 observations at that site. Total carbon and elemental carbon concentrations at Pasadena were lower, 17.1 μg m^{-3} and 5.3 μg m^{-3} respectively, based on 25 samples taken. Each aerosol carbon sample is matched by a simultaneous but independent measurement taken by the Km samplers and recorded in Km units. The average response of the Km samplers operating in parallel with the aerosol carbon experiments was 4.1 Km units at Los Angeles and 1.9 Km units at Pasadena.

Elemental carbon concentrations shown in Figure 1 were obtained by the reflectance method of Delumyea et al. (1980) applied to the quartz fiber low-volume filter samples. As a check on those data, 10 filters taken at Los Angeles and 6 filters from Pasadena that had been analyzed by reflectance also were evaluated for elemental carbon by thermal evolution followed by GRALE analysis (Delumyea et al., 1980). The 10 Los Angeles samples showed a mean elemental carbon concentration of 13.7 ($\pm$ 1.3) μg m^{-3} by reflectance and a mean elemental carbon concentration of 15.0 ($\pm$ 2.1) μg m^{-3} by GRALE. The 6 Pasadena filters yielded a mean elemental carbon concentration of 8.5 ($\pm$ 2.7) μg m^{-3} by reflectance compared to a mean elemental carbon concentration of 6.5 ($\pm$ 2.3) μg m^{-3} by GRALE. Comparison of all 16 samples gave a mean of 11.7 ($\pm$ 1.4) μg m^{-3} by reflectance versus a mean of 11.8 ($\pm$ 1.8) μg m^{-3} by GRALE. Values in parentheses represent one standard deviation of the sample means. It was concluded that on the average the two methods give the same results.

A calibration curve relating Km sampler response to elemental carbon present was constructed as shown in Figure 2 (Conklin et al., 1981). A regression line drawn through those data has the equation

$$\begin{array}{lll} EC = 2.24\ Km + 0.38 & & n = 53 \\ \quad (0.078) \quad (0.30) & & \rho = 0.97 \end{array} \qquad (3)$$

where EC is elemental carbon by reflectance in $\mu g\ m^{-3}$ taken from the quartz fiber low-volume filter samples. Values in parentheses represent one standard error on those coefficient estimates and n indicates the number of samples taken. Elemental carbon concentrations by the laboratory reflectance method and Km sampler response are linearly related with near zero intercept and a correlation coefficient, ρ, of 0.97. Use of equation (3) permits conversion of archived numerical data available in Km units into the equivalent response of a calibrated laboratory method for elemental carbon. If elemental carbon were measured by GRALE, the uncertainty in the slope and intercept of equation (3) would be larger as shown by the intermethod comparison of equation (2).

4.0 Analysis of Archived High Volume Sampler Filters

Since the 1950's, aerosol samples have been collected throughout the United States by high volume sampling by the National Air Surveillance Network (NASN). Many of the actual filters used have been archived as physical evidence of the pollutant concentrations present in past years. Since elemental carbon is chemically very stable and

quite non-volatile, it should be possible to measure historical elemental carbon concentrations using recently developed instrumentation by analyzing fragments of these archived filters.

NASN filters taken during the year 1975 at 66 sites in the United States have been analyzed for organic and elemental carbon (Huntzicker et al., 1982; Shah, 1981). Aerosol carbon determination was performed by the thermal-optical method of Huntzicker et al. (1982) and Johnson et al. (1981). In this procedure, four 0.25 cm^2 punches taken from a filter are placed into a temperature programmed oven. Organic carbon is volatilized in two steps: at 350°C in an O_2(2%)-He mixture and at 600°C in He. The volatilized organic carbon is oxidized to CO_2, then converted to methane. Methane produced is measured by a flame ionization detector. Elemental carbon is then measured by combusting the residual carbon on the sample to CO_2 in O_2(2%)-He at 400, 500 and 600°C, followed by methanation and detection as described above. If pyrolytic conversion of organic carbon to elemental carbon occurs, correction is accomplished by determining the amount of elemental carbon combustion needed to restore the reflectance of each filter to the value it had prior to pyrolysis.

NASN samples used in this study were collected over 24-hour averaging times on glass fiber filters at approximately 12 day intervals yielding up to 28 filters during 1975 at each location. A fragment of each filter was stored at room temperature until withdrawn for reanalysis during 1980-81. The effect of such storage on organic aerosol concentrations was investigated by reevaluating aerosol carbon

samples originally analyzed during the Portland Aerosol Characterization Study (PACS) (Watson, 1979). It was found that the PACS samples lost about 20% of their total carbon loading during a storage period of three years. Thus organic carbon concentrations derived from the analysis of archived NASN high volume sampler filters must be treated as a lower limit on the actual organic aerosol concentrations originally present.

Annual mean organic and elemental carbon concentrations for the year 1975 measured from archived NASN filters are shown at six Southern California sites in Figure 3. The average ratio of total carbon to elemental carbon in those samples is about 2.9 to 1, not greatly different from the total carbon to elemental carbon ratio present in the 1980 winter morning samples pictured in Figure 1 (Pasadena 3.2 to 1; Los Angeles 2.7 to 1). Organic carbon may have been lost from the 1975 samples during storage, as noted previously, so the 2.9 to 1 ratio is a lower limit on the actual long term ratio of total carbon to elemental carbon. Annual mean elemental and total carbon concentrations are lower than the winter morning sample means pictured in Figure 1, as expected since the winter sampling schedule was deliberately chosen to capture peak concentration events.

The 1975 high volume sampler data provide a second opportunity to calibrate the South Coast Air Quality Management District Km samplers' response in terms of equivalent elemental carbon concentrations. Historical Km data for 1975 were obtained on magnetic tape (Davidson, 1982). 24-hour average Km values were computed and associated with

each of the elemental carbon samples available at the Los Angeles and Pasadena monitoring sites during 1975 as shown in Figure 4. Linear regression of elemental carbon concentrations on Km values yields an expression very similar to the results of the winter 1980 study.

$$\underset{(0.19)\quad(0.56)}{EC = 2.02\ Km - 0.43} \qquad n = 54,\ \rho = 0.82 \qquad (4)$$

where EC is again elemental carbon concentration in $\mu g\ m^{-3}$ and the values in parentheses represent one standard error on the coefficient estimates. In this case, the best estimate of the slope of the calibration curve is about 10% lower than in equation (3) and the intercept is slightly negative, but the coefficient estimates do not differ significantly in a statistical sense. Elemental carbon concentrations from the 1975 filter analysis were measured independently in a different laboratory by methods different from the winter 1980 study. The near equivalence of the relationship between elemental carbon concentrations and Km sampler response at the same monitoring sites between these two experiments is encouraging.

A Km sampler also was located at the Burbank monitoring site shown in Figure 3 during 1975. Combining the Burbank data set with the 1975 data at Los Angeles and Pasadena and repeating the regression analysis, one obtains:

$$\underset{(0.15)\quad(0.48)}{EC = 1.78\ Km + 0.50} \qquad n = 77,\ \rho = 0.81 \qquad (5)$$

The Burbank data set contains one extreme outlying data point that may be due to having run the high volume sampler on a day other than that reported or, to having run the hi vol for more than one 24 hr period.

5.0 Estimation of an Historical Data Base for Elemental Carbon Concentrations

The results of the 1975 NASN filter analysis were combined with data from the 1980 winter experiment. A pooled estimate of the relationship between Km sampler response and elemental carbon concentrations was obtained by regression analysis:

$$\underset{(0.09)\quad(0.31)}{EC = 2.09\ Km + 0.13} \qquad n = 130,\ \rho = 0.90 \qquad (6)$$

where elemental carbon concentrations, EC, again are stated in $\mu g\ m^{-3}$. Values in parentheses indicate one standard error about those coefficient estimates.

Km sampler data taken over the period 1958-1981 were acquired on magnetic tape from the South Coast Air Quality Management District (Davidson, 1982). Using Equation (6) those data were converted to equivalent elemental carbon concentrations at seven sites in the Los Angeles area. As shown in Figure 5, long-term mean elemental carbon concentrations do not differ greatly from the results of the 1975 NASN filter analysis. Mean elemental carbon concentrations over that 24 year period range from 6.4 $\mu g\ m^{-3}$ at Downtown Los Angeles to 4.5 $\mu g\ m^{-3}$ at West Los Angeles.

As seen in Figure 6, the long term trend in elemental carbon concentrations at most sites in the Los Angeles area is downward over the period 1958-1981. Particularly high elemental carbon concentrations, in some cases above 30 $\mu g\ m^{-3}$ 24-hour average, are estimated to have occurred during the winter of 1958-59 at a number of monitoring sites, with no values approaching that level in recent years. Two more formal means for detecting long term trends in the data base were applied. First the 24-hour average elemental carbon estimates were regressed against time. As shown in Table 2, light absorbing aerosol concentrations generally have been decreasing at Downtown Los Angeles, Pasadena, Lennox, Burbank and West Los Angeles. West Los Angeles shows both the fastest rate of improvement and the best air quality for this pollutant. Elemental carbon concentrations at Azusa have increased over the time span shown.

Next the time series of 24-hour average elemental carbon concentration estimates were passed through a linear digital filter.[1] This processing removes fluctuations in the data base with frequency greater than four cycles per year leaving seasonal variations intact. The filtered data are shown in Figure 7. A strong seasonal peak in light absorbing material in the Los Angeles atmosphere is apparent in the late fall and early winter of nearly every year. This seasonal

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[1] The filter's characteristics are such that it returns the low frequency signal with unit gain, half power cutoff set to remove disturbances with frequency greater than four cycles per year, and roll off at the half power point of 20 db per octave. For a discussion of digital filtering methods see Bendat and Piersol (1971).

behavior matches that of inert motor vehicle derived pollutants, like lead, that are emitted at a more or less constant rate throughout the year, but that rise in concentration in the winter in Los Angeles due to poor atmospheric dispersion conditions at that time of year (for lead data, see Cass and McRae, 1983). If the majority of elemental carbon emissions in Los Angeles come from diesel engines as was estimated by Cass et al. (1982), then the seasonal variation in elemental carbon air quality would be similar to that seen in Figures 6 and 7. A small increase in total fuel burning occurs in Los Angeles in the winter, and the winter increase in elemental carbon air quality may also be assisted by higher winter emissions. An increase in elemental carbon concentrations at Downtown Los Angeles is apparent during 1981, and should be monitored closely to see if that upward movement is part of a sustained increase in concentrations at that site.

6.0 Conclusions

Two approaches are available for the estimation of an historical data base for elemental carbon concentrations. Reflectance-based tape samplers can be calibrated to read in units of equivalent elemental carbon concentration. Alternatively, archived fragments of high volume sampler filters can be analyzed by modern instrumentation to determine their elemental carbon content.

Each of these methods has a number of advantages and disadvantages. Calibration of reflectance-based tape samplers has the advantage that literally thousands of hourly pollutant concentration

estimates can be recovered for the expense of analyzing a relatively small number of parallel filter samples for their elemental carbon content. If one-hour time resolution were necessary in the resulting historical data base, then this is probably the only method available. Disadvantages of the tape sampler calibration method include the fact that reflectance is only an indirect measure of elemental carbon concentration. If one wished to examine data in a community where light absorption by iron particles, for example, constituted a significant fraction of total aerosol light absorption, then this method would be inappropriate. Furthermore, the characteristic morphology and hence reflectance of ambient elemental carbon particles might vary from one community to another as a function of differences in local pollution sources. Until these possibilities are better understood, it is important to conduct parallel sampling effort such as those used by Conklin et al. (1981) before any tape sampler's data are interpreted in terms of elemental carbon concentrations.

A major advantage of the archived filter analysis method for historical elemental carbon concentrations lies in the fact that elemental carbon concentrations are determined directly from a physical sample of the aerosol of interest. Disadvantages include uncertainties surrounding sample integrity during many years of filter handling and storage. Archived filter sets generally do not provide continuous data, and filters taken many years ago may have been discarded.

Using these methods, an historical data base for elemental carbon concentrations was estimated for the Los Angeles area. It was found that elemental carbon concentrations averaged over the past quarter century ranged from a high of 6.4 $\mu g\ m^{-3}$ at Downtown Los Angeles to a low of 4.5 $\mu g\ m^{-3}$ at West Los Angeles. 24 hour average elemental carbon concentrations in the late 1950's occasionally exceeded 30 $\mu g\ m^{-3}$. In general, elemental carbon concentrations have declined at most monitoring sites over the 24 year period studied, with 24-hour average elemental carbon concentrations very rarely exceeding 20 $\mu g\ m^{-3}$ in recent years.

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TABLE 1

Summary of Aerosol Carbon Measurement Program

EXPERIMENT	PARAMETER MEASURED	SAMPLING DEVICE	SAMPLE DURATION	FILTER SUBSTRATE	ANALYTICAL TECHNIQUE	REFERENCE
Winter 1980	Organic Carbon	Low Vol Filter	51.5 min	Quartz Fiber	GRALE	Macias et al. (1978)
	Elemental Carbon[a]	Low Vol Filter	51.5 min	Quartz Fiber	Elemental Carbon by Reflectance	Delumyea et al. (1980)
	Elemental Carbon[a]	Low Vol Filter	51.5 min	Quartz Fiber	Elemental Carbon by GRALE	Delumyea et al. (1980)
	Particulate Matter in Km Units	Km Sampler (Chaney Aerosol Recorder)	51.5 min	Paper Tape	Reflectance meter built into recorder; read in Km units	Hall (1952); Holland and MacPhee (1958)
	Aerosol Light Absorption Coefficient[b]	Low Vol Filter	51.5 min	Nuclepore Filter	Light absorption	Lin et al. (1973); Ouimette (1980)
	Trace Metals[b]	Low Vol Filter	51.5 min	Nuclepore Filter	X-ray fluorescence	
	Aerosol Mass Concentration[b]	Low Vol Filter	51.5 min	Nuclepore Filter	Gravimetric	
1975 Filter Analysis	Organic Carbon	NASN Hi Vol	24 hr	Glass Fiber	Volatilization and combustion with pyrolysis correction	Huntzicker et al. (1982); Johnson et al. (1981)
	Elemental Carbon	NASN Hi Vol	24 hr	Glass Fiber	Volatilization and combustion with pyrolysis correction	Huntzicker et al. (1982); Johnson et al. (1981)
	Particulate Matter in Km Units	Km Sampler (Chaney Aerosol Recorder)	average of 24 hourly samples	Paper Tape	Reflectance meter built into recorder; read in Km units	Hall (1952); Holland and MacPhee (1958)

Notes: (a) All samples were analyzed for elemental carbon by reflectance, then a subset of 16 of those filters were analyzed for elemental carbon by GRALE.
(b) Not used in this paper; for light absorption results see Conklin et al. (1981).

Table 2

Long Term Trend: Elemental Carbon Concentrations Regressed on Time

MONITORING SITE	INTERCEPT AND SLOPE OF TREND LINE WITH TIME
Downtown Los Angeles	EC = 7.3 (0.08) − 0.08 t (0.006)[a][b]
Pasadena	EC = 6.7 (0.06) − 0.10 t (0.004)
Burbank	EC = 6.9 (0.08) − 0.05 t (0.007)
Long Beach	EC = 5.1 (0.08) + 0.01 t (0.007) NS[c]
Azusa	EC = 4.2 (0.05) + 0.04 t (0.004)
West Los Angeles	EC = 5.8 (0.07) − 0.12 t (0.006)
Lennox	EC = 5.9 (0.10) − 0.06 t (0.007)

(a) Time, t, is in years; January 1, 1958 = 0.0.
(b) Values in parentheses represent one standard error on the coefficient estimates.
(c) NS indicates that coefficient is not significantly different from zero at a 95% confidence level.

FIGURE CAPTIONS

Figure 1 — Results of the Ambient Sampling Program - January and February 1980. Pollutant concentrations are mean values for the hours 7:00 am to 1:00 pm.

Figure 2 — The relationship between elemental carbon concentration and Km sampler response. Elemental carbon concentrations shown are determined by the reflectance method of Delumyea et al. (1980).

Figure 3 — Results of the 1975 NASN filter analysis experiments. Pollutant concentrations are annual means. Total carbon and elemental carbon determinations are by the thermal-optical method of Huntzicker et al. (1982).

Figure 4 — The relationship between elemental carbon concentration and Km sampler response. Elemental carbon concentrations shown are determined by the thermal-optical method of Huntzicker et al. (1982).

Figure 5 — Average elemental carbon concentrations estimated from historical Km data in the Los Angeles Basin 1958-1981, in $\mu g\ m^{-3}$.

Figure 6 — Elemental Carbon Concentration and Km Values

Figure 7 — Trend in Elemental Carbon Concentration and Km Values

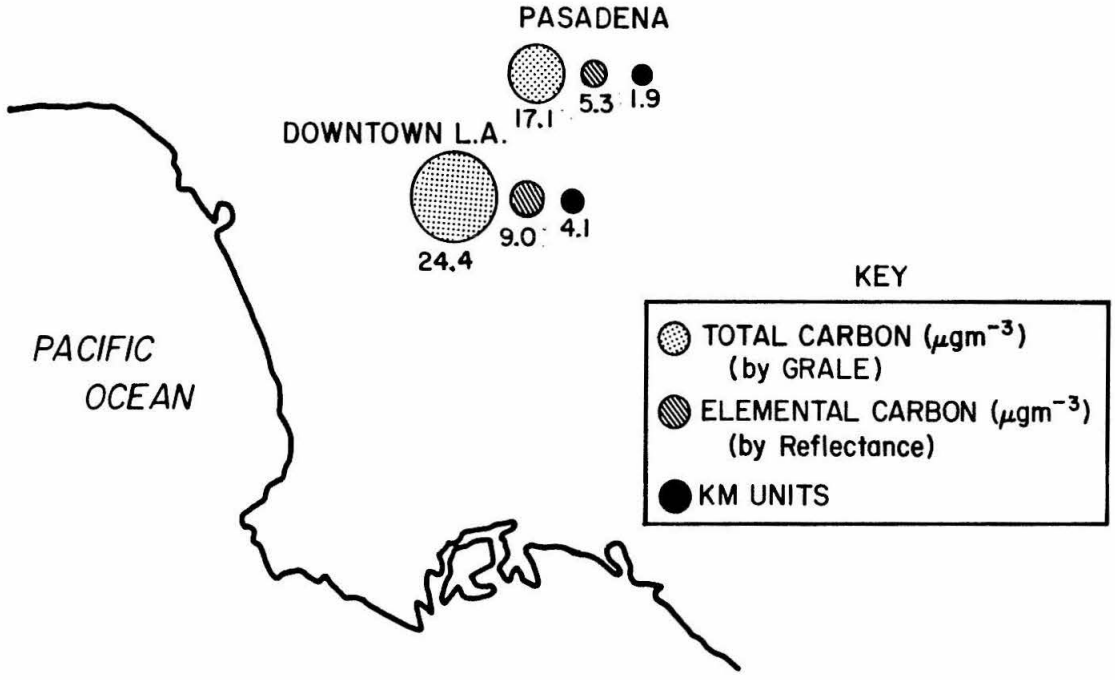
PASADENA
17.1
5.3
1.9
DOWNTOWN L.A.
24.4
9.0
4.1
PACIFIC
OCEAN
KEY
TOTAL CARBON (μgm⁻³)
(by GRALE)
ELEMENTAL CARBON (μgm⁻³)
(by Reflectance)
KM UNITS

FIGURE 1

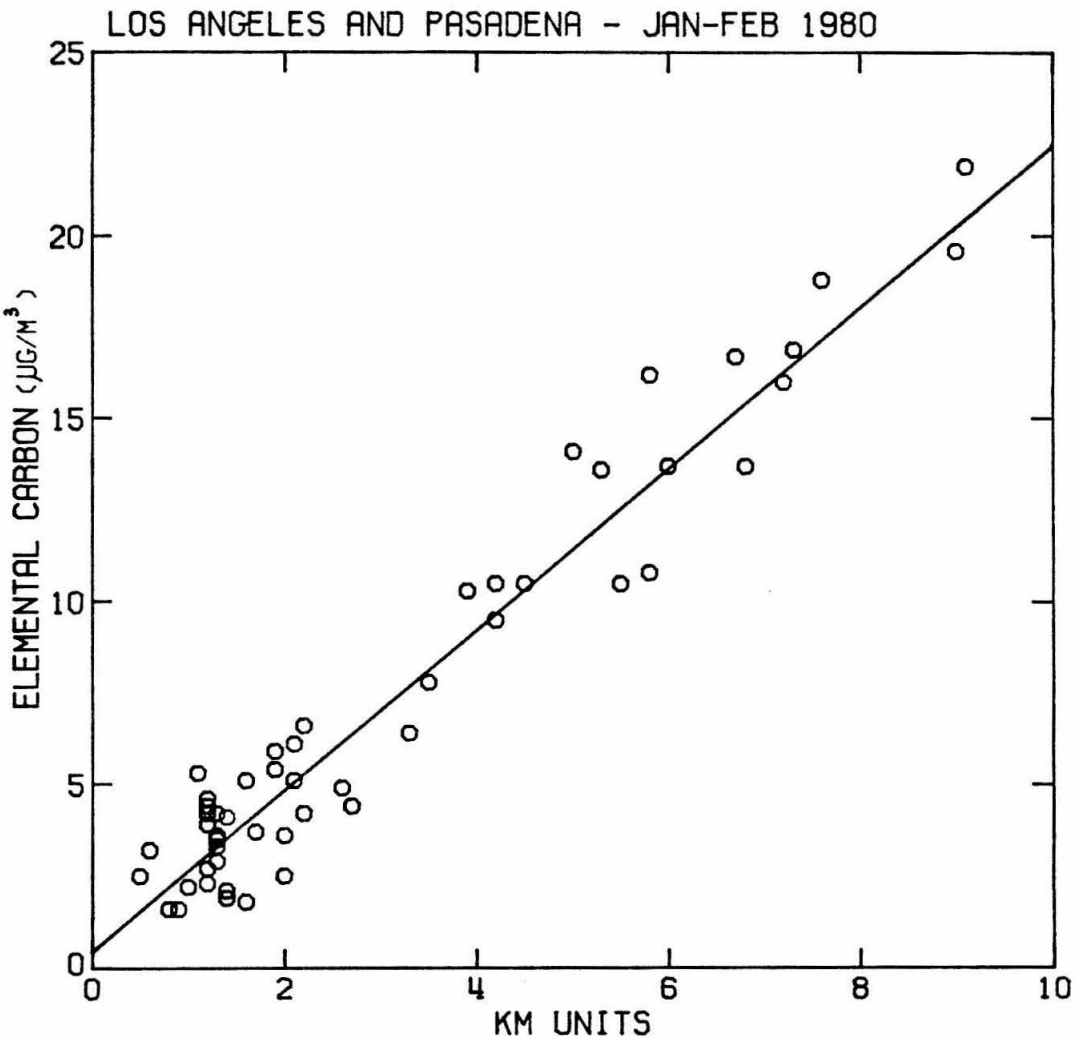
LOS ANGELES AND PASADENA - JAN-FEB 1980
ELEMENTAL CARBON (μG/M³)
KM UNITS
0
5
10
15
20
25
0
2
4
6
8
10

FIGURE 2

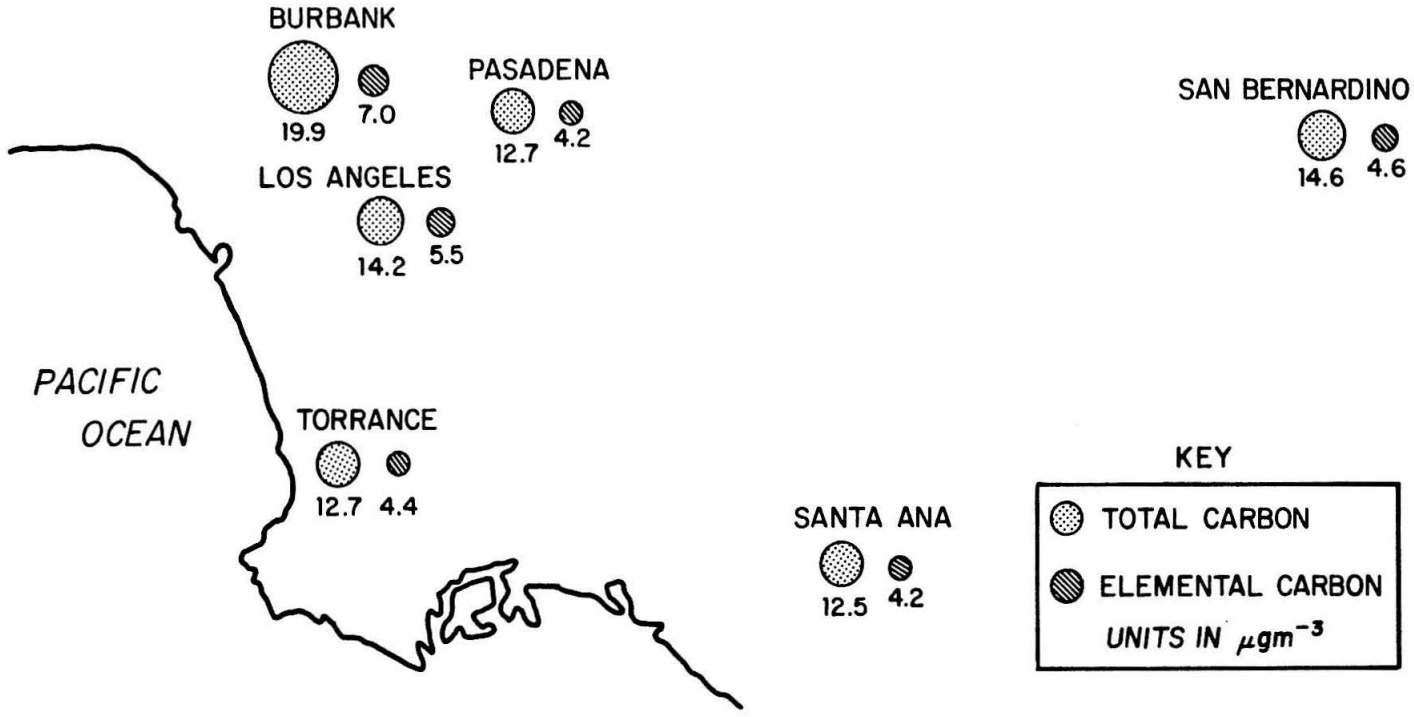
BURBANK
19.9
7.0
PASADENA
12.7
4.2
SAN BERNARDINO
14.6
4.6
LOS ANGELES
14.2
5.5
PACIFIC
OCEAN
TORRANCE
12.7
4.4
SANTA ANA
12.5
4.2
KEY
TOTAL CARBON
ELEMENTAL CARBON
UNITS IN μgm⁻³

FIGURE 3

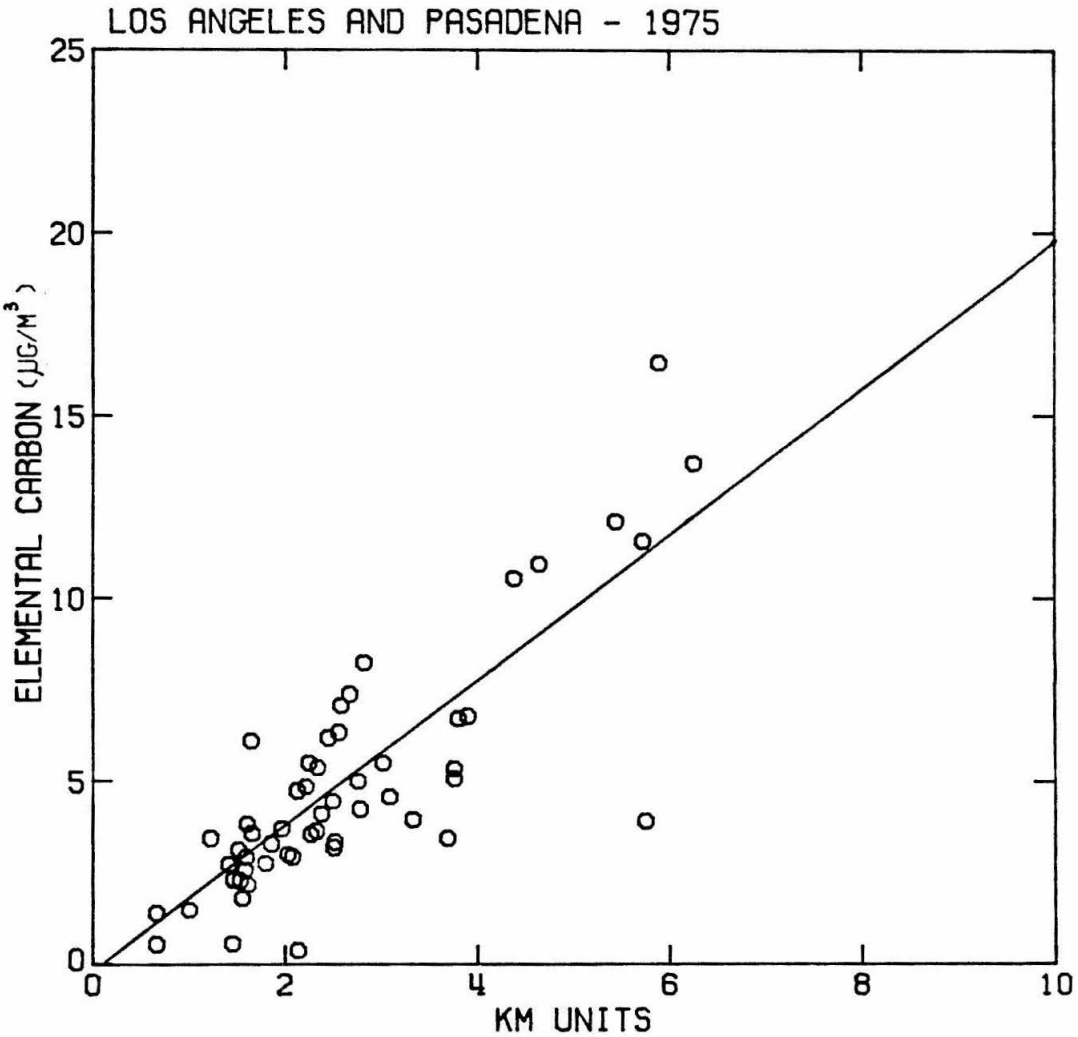
LOS ANGELES AND PASADENA - 1975
ELEMENTAL CARBON (μG/M³)
KM UNITS
0
5
10
15
20
25
0
2
4
6
8
10

FIGURE 4

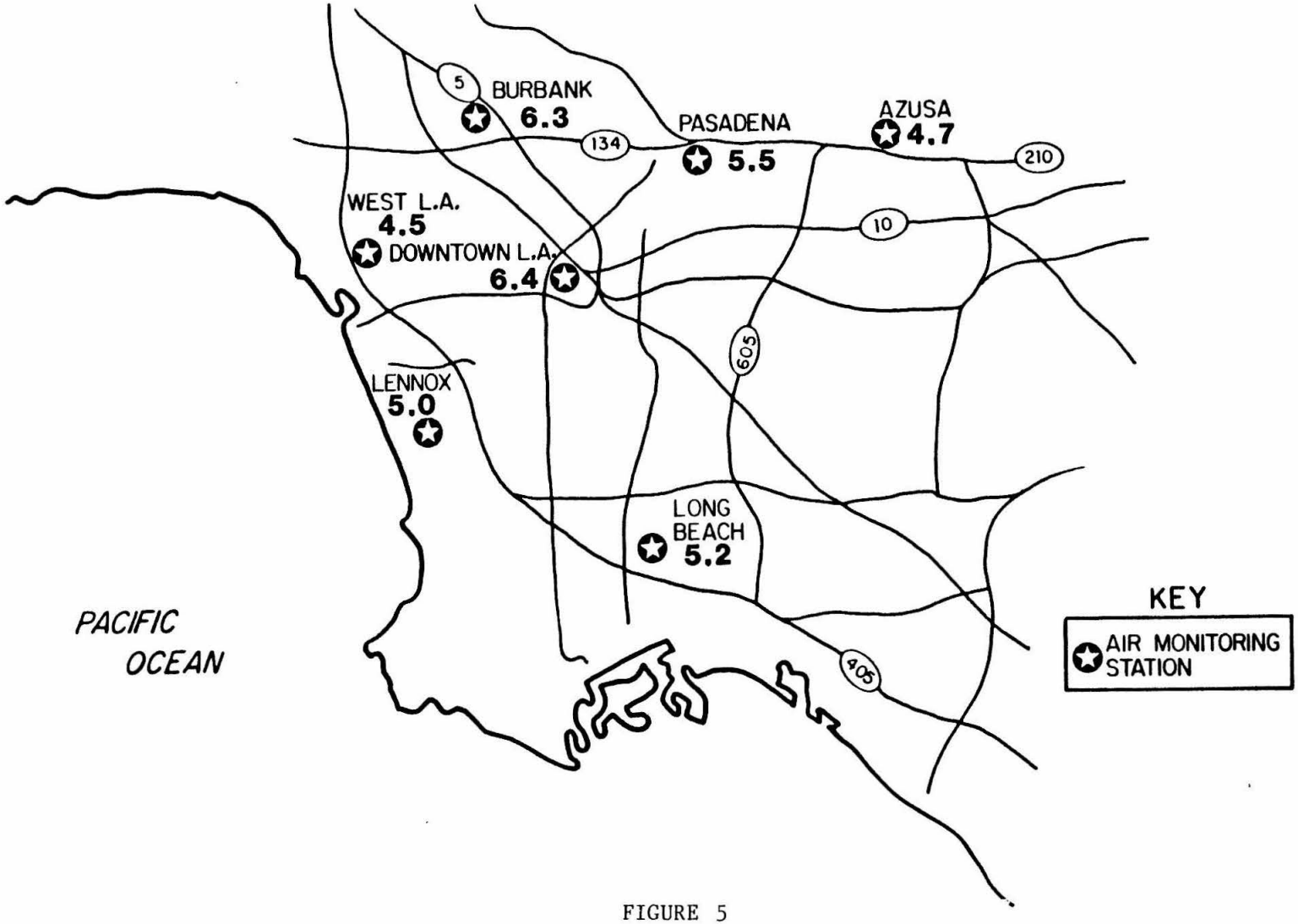
5
BURBANK
6.3
134
PASADENA
5.5
AZUSA
4.7
210
WEST L.A.
4.5
DOWNTOWN L.A.
6.4
10
605
LENNOX
5.0
LONG
BEACH
5.2
405
PACIFIC
OCEAN
KEY
AIR MONITORING
STATION

FIGURE 5

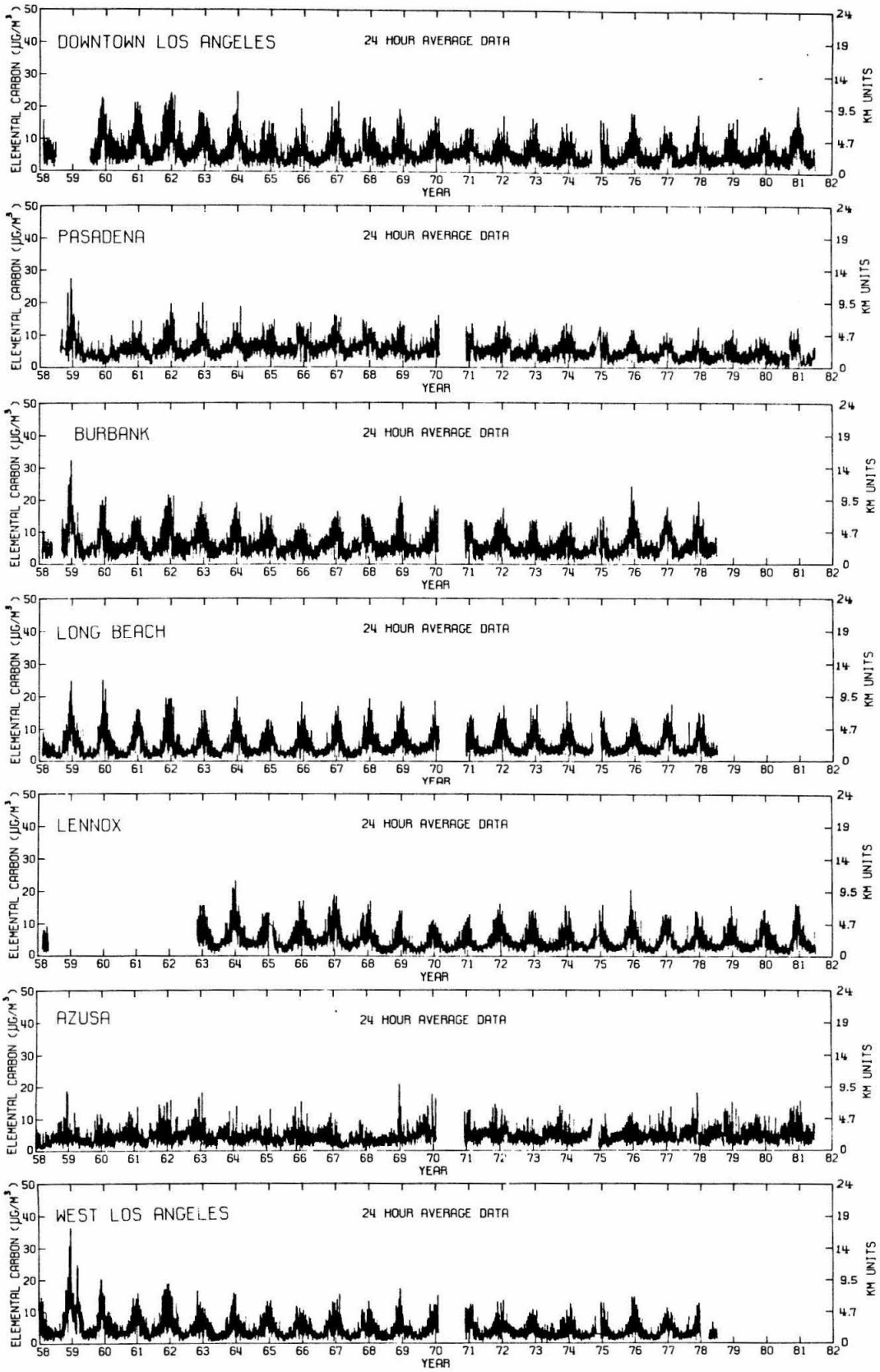
DOWNTOWN LOS ANGELES
24 HOUR AVERAGE DATA
PASADENA
24 HOUR AVERAGE DATA
BURBANK
24 HOUR AVERAGE DATA
LONG BEACH
24 HOUR AVERAGE DATA
LENNOX
24 HOUR AVERAGE DATA
AZUSA
24 HOUR AVERAGE DATA
WEST LOS ANGELES
24 HOUR AVERAGE DATA
ELEMENTAL CARBON (μG/M³)
KM UNITS
YEAR

FIGURE 6

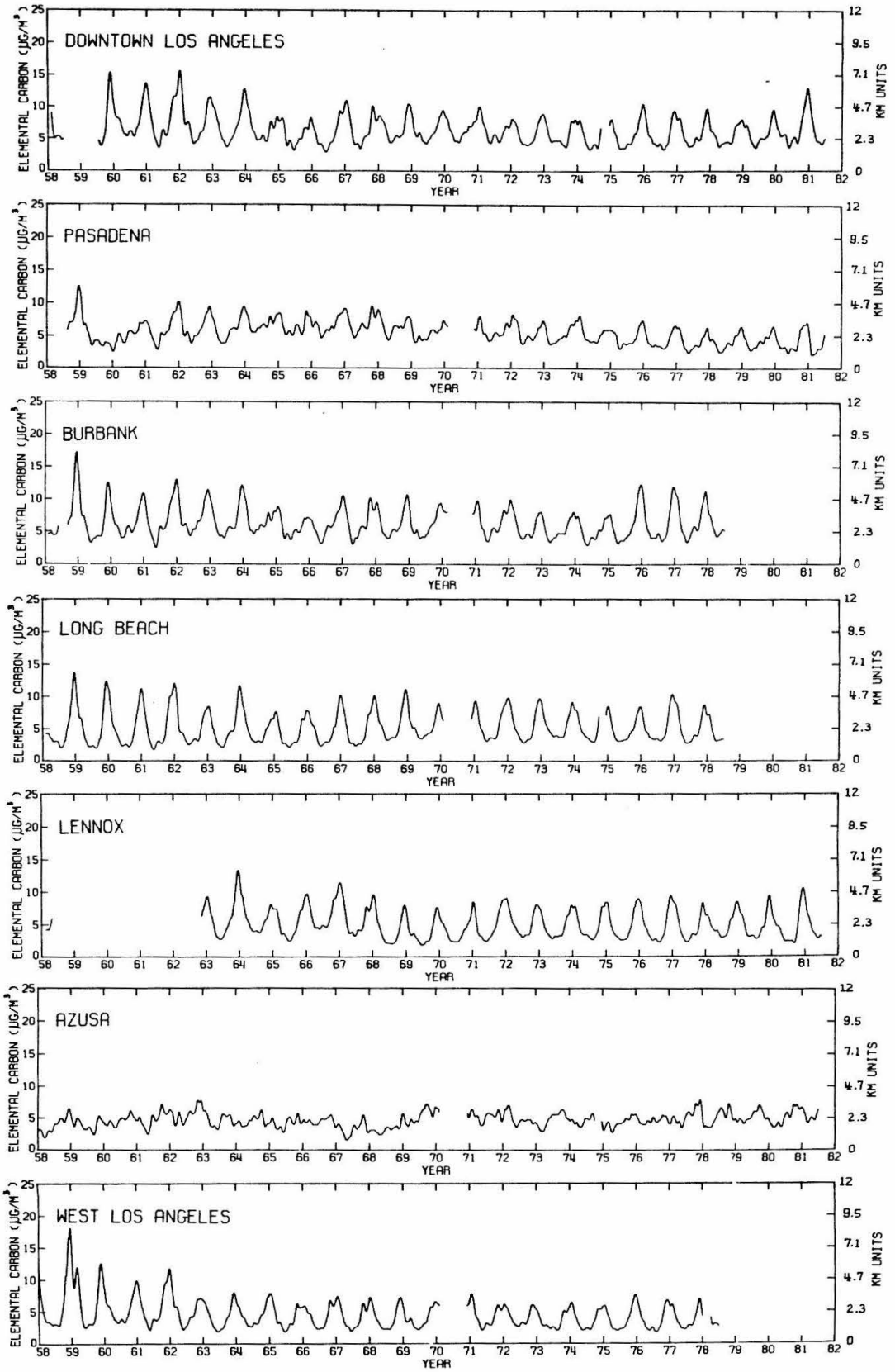
DOWNTOWN LOS ANGELES
PASADENA
BURBANK
LONG BEACH
LENNOX
AZUSA
WEST LOS ANGELES
ELEMENTAL CARBON (μG/M³)
KM UNITS
YEAR
0
5
10
15
20
25
0
2.3
4.7
7.1
9.5
12
58
59
60
61
62
63
64
65
66
67
68
69
70
71
72
73
74
75
76
77
78
79
80
81
82

FIGURE 7